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THE PRECIPITATION OF RADIOACTIVE RADIUM^{226} FROM ACIDIC CHLORIDE LEACH LIQUORS WITH BARIUM CHLORIDE - PROGRESS REPORT NO. 6

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July 1983

Project ERP- 4.4.1.0.02
Uranium Extraction - Alternative

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17pp

ENERGY RESEARCH PROGRAM
MINERAL SCIENCES LABORATORY
DIVISION REPORT ERP/MSL 83-106(TR)

MICROMEDIA
JAN 20 1984

THE PRECIPITATION OF RADIOACTIVE RADIUM^{226} FROM ACIDIC CHLORIDE LEACH LIQUORS WITH BARIUM CHLORIDE - PROGRESS REPORT NO. 6

by

A.J. Gilmore

SUMMARY

The conventional barium chloride ($BaCl_2$) precipitation has been effective in the 99+% removal of radium^{226} (Ra^{226}), as radium-barium sulphate [$RaBa(SO_4)_2$] sludge, from HCl liquors produced by laboratory and pilot leaches of Canadian uranium ores. Radium^{226}, due to its low-level radiation characteristics, is removed as it has been identified as an environmental and long-term health problem. The formation of the $RaBa(SO_4)_2$ sludge was aided due to adequate sulphate (SO_4) concentrations in the HCl pilot liquors produced. Recyclable Ra^{226} concentrations of about 66 pCi/L, in treated effluents, will cost about 1/10 (see Table 5) that of effluents below federal environmental guidelines of 10 pCi Ra^{226}/L. Toxic barium (Ba) will potentially build up in effluents at recyclable Ra^{226} concentrations around 66 pCi/L. Barium, in addition to being added to liquors as $BaCl_2$ precipitant, is present in the radioactive ore and HCl leach liquors.

Energy Research Program, Mineral Sciences Laboratory, CANMET, Energy, Mines and Resources Canada, Ottawa

ON DE RADIUM^{226} RADIOACTIF À PARTIR DE LIQUEURS DE LIXIVIATION AU CHLORURE D'ACIDE, EN PRÉSENCE DE CHLORURE DE BARYUM - RAPPORT D'ÉVOLUTION N^{O} 6

par

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RÉSUMÉ

Le procédé classique de précipitation dans une solution de chlorure de baryum ($BaCl_2$) permet de récupérer [sous forme de boue sulfatée de radium-baryum $RaBa(SO_4)_2$] au moins 99% du radium^{226} (Ra^{226}) que contiennent les liqueurs de HCl résultant de la lixiviation, en laboratoire et à l'usine pilote, de minerais radioactifs canadiens. On effectue cette récupération en raison de la faible radioactivité du radium^{226} qui est signalée comme source de pollution et de problèmes de santé à long terme. La formation de la boue de $RaBa(SO_4)_2$ est facilitée par la présence, en concentrations suffisantes, de sulfate (SO_4) dans les liqueurs expérimentales de HCl produites. La récupération du Ra^{226}, concentré à environ 66 pCi/l dans les effluents traités, coûtera approximativement dix fois moins (voir tableau 5) que l'enlèvement du radium d'effluents où la concentration excède les normes environnementales fédérales de 10 pCi Ra^{226}/l. Du baryum (Ba) toxique pourrait éventuellement s'accumuler dans les effluents lorsque la concentration de Ra^{226} récupérable atteint environ 66 pCi/l. Outre d'être ajouté à des liqueurs comme réactif précipitant de $BaCl_2$, le baryum est présent dans le minerai radioactif et dans les liqueurs de lixiviation de HCl.

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INTRODUCTION

The objective of this work was to study the removal of radium^{226} (Ra^{226}) from acidic chloride leach liquors by precipitation with conventional barium chloride ($BaCl_2$). Radium^{226}, as discharged from current uranium milling operations in sulphated solids and barium effluents, is a public concern because of the long-term health and environmental effects of the low-level radiation from Ra^{226}. The solid residue discharged, in the acidic sulphate leaching process, retains most of the Ra^{226}, while the bulk of the Ra^{226} is dissolved with the acidic chloride leaching process. Consequently, an evaluation study has been in progress at CANMET on the potential of the acidic chloride leaching for U, Th, and Ra^{226} removal from uranium ores, in place of the well-developed acidic sulphate leaching technology.

Tailings pond effluents from conventional H_2SO_4 leaching circuits, contain 600 to 1200 pCi Ra^{226}/L. A barium chloride ($BaCl_2$) addition to the effluents, before discharge to the water environment, precipitates a radioactive radium-barium sludge. Tailings ponds or dumps retain this sludge within the mine property boundaries. Discharged effluents, from $BaCl_2$ precipitation, to the receiving water environment should be 10 pCi Ra^{226}/L or less to meet federal environmental guidelines.

A hydrochloric (HCl) acid leach[1] or a chlorination roast-leach[2] of a radioactive uranium ore would produce chloride liquors bearing Ra^{226}. The removal of Ra^{226} from chloride liquors, by cation-exchange processing, has been examined in CANMET laboratories. Ra^{226} removal from chloride solutions has been reported from relatively pure solutions of Ra^{226} alone, 1) by column adsorption[3]; 2) Ra^{226} in the presence of Ca, Mg and Fe cation, by batch adsorption[4]; 3) columnar adsorption[5]; and 4) from pilot-plant acidic chloride liquors with inorganic and organic batch adsorption[6]. The consequences of precipitating Ra^{226} from HCl leach liquors, with conventional $BaCl_2$ will be examined in this study, for comparison with above studies.

PROCEDURE

Barium chloride, as $BaCl_2 \cdot 2H_2O$ in solid and in solution form, was added to roughly one litre volumes of HCl leach liquors from laboratory batch

leach and pilot-plant work. pH-variations with $CaCO_3$ additions were attempted. H_2SO_4 was added as a source of SO_4 for formation of Ra/Ba $(SO_4)_2$ precipitate in a chloride media, in some tests. Tests were allowed additional mechanical or aeration agitation time after reagent addition. The precipitate was then allowed 72 hours settling time before millipore or sand-bed filtration. The filtrate was dispatched to analytical control laboratory to determine Ra^{226} concentration by an alpha spectrometry method.

RESULTS

A composite of HCl liquors from laboratory-scale batch leaching was attempted for preliminary $BaCl_2$ precipitation of Ra^{226}. The analyses of two composite liquors is shown in Table 1.

Table 2 presents precipitation detail and analytical results. Solid $BaCl_2.2H_2O$ was added as 10 mg $BaCl_2$/L for every 500 pCi Ra^{226}/L. The addition of $CaCO_3$ to pH 2.0 and 4.36, in first two tests, produced iron cakes containing up to 200 pCi Ra^{226}/g. Ra^{226} concentration varied from E15 to 150 pCi Ra^{226}/L. Best decant filtrate from Rio Algom liquors assayed E15 to 150 pCi Ra^{226}/L. Filtrate, with no pH-adjustment assayed 30 pCi Ra^{226}/L. Ra^{226} removal was 98.8% to 99.9%.

Table 3 shows the analysis of 2nd stage HCl recycled liquor from pilot leach of Denison Mines Ltd. ore, plus washes. Considerable difference exists, in liquors, between preliminary work on lab-scale batch HCl-liquors and pilot-leach liquors. The latter liquor is lower in Ra^{226}, Fe, Th, Ca, Mg and K concentration but much higher in free HCl level.

Table 4 shows the results of Ra^{226} precipitation tests on the 2nd stage HCl pilot leach of Denison ore. Tests 1 to 6 averaged only 57.6% removal of Ra^{226}, ranging from 40.7% to 94.5% with filtrates ranging from 260 to 2820 pCi Ra^{226}/L. Tests with Ottawa sand C-109, as a 1/2 in. x 19 in. filter bed in place of millipore filter, indicated sand bed filters five times better than millipore filter. Sand in 1/2 in. diam x 19 in. column was more effective than a 3 in. x 2-1/2 in. sand bed. The method of $BaCl_2$ addition was changed, in tests 7 to 26, from solid to solution addition, as a solution of 35.7 g $BaCl_2.2H_2O$/100 mLs H_2O. The reason being that $BaCl_2.2H_2O$ is "slightly

Table 1 - Analysis of Rio Algom HCl feed liquors from laboratory batch leaching

	Assays	
Determination	Liquor No. 1 pH = 0.61	Liquor No. 2 from flotation conc pH = 1.03
Ra^{226}	12,300 pCi/L	13,900 pCi/L
U	0.82 g/L	0.26 g/L
Th	0.28 g/L	0.12 g/L
Fe^{total}	6.59 g/L	2.27 g/L
Fe^{2+}	2.71 g/L	-
Al	1.42 g/L	0.38 g/L
Mg	0.3 g/L	0.094 g/L
K	0.43 g/L	0.25 g/L
Na	0.45 g/L	0.14 g/L
Si	0.38 g/L	0.13 g/L
Ca	0.75 g/L	0.30 g/L
SO_4=	-	0.78 g/L
Cl	30.4 g/L	-
Free HCl	10.1 g/L	4.16 g/L

soluble in HCl"* - and the free HCl in the recycle HCl liquor being 0.63 N. The solid addition of $BaCl_2 \cdot 2H_2O$ probably resulted in latent or non-solubility of some $BaCl_2 \cdot 2H_2O$ in the 0.63 NHCl. The free HCl level, in the Rio Algom liquors, was considerably lower, at 0.11 to 0.28 N. Mechanical agitation, also, was changed to aeration agitation. These changes improved Ra^{226} removal from 57% to a range of 98.3 to 99.9%, with an average of 98.9%. The filtrates also improved from about 2500 pCi Ra^{226}/L to a range of <5 to 672 pCi Ra^{226}/L. The change in $BaCl_2$ addition resulted in a vast improvement in attaining low Ra^{226} concentrations. The aeration aided in forming colloids, which settled in a deep tank (1 L cylinder) over a 72 hour period.

* Chemical Rubber Co., "Handbook of Chemistry and Physics", 43rd and 52nd Editions in 1961 and 1971 respectively.

Table 2 - Precipitation of Ra^{226} from Rio Algom Liquors with $BaCl_2$ precipitant

Pptn. Test	Feed Liquor No.	Stage Pptn. Reagents & pH	Solid $BaCl_2 \cdot 2H_2O$ Addn/L	Additional Stirring Time	Settling Time & Filtration	Dried Ra^{226} Ppte.	Decant Filtrate Ra^{226} Assay	Comments
1	1 pH 0.61 900 ml.	15.59 g $CaCO_3$ to pH 2.0	144 mg. H_2SO_4 + 318 mg $BaCl_2 \cdot 2H_2O$	30 min.	72 h settling & decant filtered thru 0.45 µm filter.	370 mg	35 pCi/L. 99.7%	10 mg $BaCl_2$/L added for every 500 pCi Ra^{226}/L
2	1 pH 0.61 900 ml.	33.16 g $CaCO_3$ to pH 4.36	144 mg H_2SO_4 + 320 mg $BaCl_2 \cdot 2H_2O$	30 min.	"	650 mg	150 pCi/L 98.8%	14.4 g of Fe-cake was 200 pCi Ra^{226}/g.
3	2 pH 1.03 1 L	nil	144 mg H_2SO_4 + 640mg $BaCl_2 \cdot 2H_2O$	60 min. aeration & stirring	"	750 mg	30 pCi/L 99.8%	2 x $BaCl_2$ added due to uncertainty of Ra^{226}-assay not reported
4	2 pH 1.03 1 L.	6.44 g $CaCO_3$ to pH 2.01	"	30 min. aeration & & stirring	"	740 mg	<15 pCi/L. "	99.9%
5	2 pH 1.03 1 L.	9.40 g $Ca(OH)_2$ to pH 4.5. 4.39 g Fe-Cake	"	30 min. aeration & stirring. Aeration cont'd 72 h	"	630 mg	42 pCi/L. 99.7%	
6	2 pH 1.03	2 stage addn. 6.46 g $CaCO_3$ to pH 2.0 & 4.7 g $Ca(OH)_2$ to pH 4.3. 4.43 g Fe-Cake	144 mg H_2SO_4 +350 mg $BaCl_2 \cdot 2H_2O$	"	"	360 mg	43 pCi/L. 99.7%	Rec'd Ra^{226} assay & lowered $BaCl_2 \cdot 2H_2O$ addn. assay

Table 3 - Analysis of 2nd stage HCl composite recycle liquor from pilot leach of Denison Mines Ltd. ore, plus washes

Determination	Assay of HCl liquor	Determination	Assay of HCl liquor
pH	0.51	Ba	1 ppm
Ra^{226}	4760 to 4820 pCi/L	K	180 ppm
U	86 ppm	Na	240 ppm
Th	35 ppm	Si	120 ppm
Fe^{total}	700 ppm	Ti	50 ppm
Fe^{3+}	210 ppm	W	<1 to <50 ppm
Ca	52 ppm	Zr	<20 ppm
Mg	21 ppm	Mn	2 ppm
Al	410 ppm	Sn	<1 ppm
NH_4	10 ppm	SO_4	960 ppm
PO_4	20 ppm	Free HCl	22.5 to 23.1 g/L (0.63N HCL)

$CaCO_3$ was again added to study effect of pH, in tests 11 to 13. A filtrate of 6 pCi Ra^{226}/L resulted in test 11, with no precipitate at pH 1.03. Tests 12 and 23 produced filtrates of <5 and 6 pCi Ra^{226}/L - below environmental guidelines - but the filter cakes as produced, bearing Ra^{226}, would have to be disposed of as before in Table 2.

Increased amounts of $BaCl_2 \cdot 2H_2O$ were added, in tests 14 to 16, to monitor Ra^{226}, sulphate (SO_4) and toxic barium (Ba) concentrations. Doubling the $BaCl_2 \cdot 2H_2O$ addition from 1220 mg to 2440 mg $BaCl_2 \cdot 2H_2O$ (Fig. 1) lowered SO_4 and Ra^{226} levels to 9 ppm SO_4 and 70 pCi Ra^{226}/L, but increased toxic Ba-concentration to 20 ppm.

Balance of tests were repetitions of previous work with decreasing amounts of $BaCl_2 \cdot 2H_2O$ to determine the minimum amount of $BaCl_2 \cdot 2H_2O$ required to remove Ra^{226} to environmental guidelines or to economic recyclable concentrations, where there is apt to be a build-up of toxic Ba.

Table 4 - Precipitation of Ra^{226} from composite of HCl liquors + washes
- Product of 2nd stage HCl pilot leach of Denison ore

Pptn. Test	Reagent Addn/L	Additional Mechanical Stirring Time	Settling Time and Filtration	Filtrate Ra^{226} Assay	% Ra-Removal	Remarks
1.	140 mg H_2SO_4 + 973 mg $BaCl_2 \cdot 2H_2O$	30 min.	1/2 h settling + decant filtered thru 45 µm millipore filter	2820 pCi Ra^{226}/L + 1 ppm Ba	40.7%	Ra^{226} assay of feed unknown.
2.	140 mg H_2SO_4 + 973 mg $BaCl_2 \cdot 2H_2O$	"	1/2 h settling + decant filtered thru 3" x 2-1/2" sand bed.	2190 pCi Ra^{226}/L + 1 ppm Ba	54%	Ottawa sand C-109 Sand filter more effective than millipore filter.
3.	No H_2SO_4. 673 mg $BaCl_2 \cdot 2H_2O$	"	1/2 h settling + decant filtered thru 0.45 µm filter (millipore)	2360 pCi Ra^{226}/L + 1 ppm Ba	50.4%	No H_2SO_4 addn. Compared to Pptn Test #1, H_2SO_4 not required.
4.	673 mg $BaCl_2 \cdot 2H_2O$	"	1/2 h settling + 1/2 decant filtered thru 0.22 µm filter and 1/2 thru sand bed	1) 0.22 µm filter 1410 pCi Ra^{226}/L 2) Sand bed 260 pCi/L	70.4% 94.5%	Sand bed 1/2" diam x 19" deep. 0.22 µm filter better than 0.45 µm filter. Sand bed better than 0.22 µm filter
5.	140 mg H_2SO_4 + 337 mg $BaCl_2 \cdot 2H_2O$	"	1/2 h settling + decant filtered thru 0.22 µm millipore	2590 pCi Ra^{226}/L + 0.9 ppm Ba	45.6%	Ra-removal improved in absence of H_2SO_4 addn & reduced $BaCl_2$ addn. Compare to tests 1 & 4
6.	140 mg H_2SO_4 + 337 mg $BaCl_2 \cdot 2H_2O$	"	1/2 h settling + decant filtered thru sand bed	2490 pCi Ra^{226}/L + 0.9 ppm Ba	47.7%	Sand bed 1/2" x 19" deep. Sand bed slightly better than millipore filter.
7.	673 mg $BaCl_2 \cdot 2H_2O$ dissolved & added as soln. No H_2SO_4	"	"	68 pCi Ra^{226}/L + 1 ppm Ba	98.6%	Low filtrate without H_2SO_4 or alkali addition.
8.	140 mg H_2SO_4 + 673 mg $BaCl_2 \cdot 2H_2O$ added as soln (see Test 18)	"	"	45 pCi Ra^{226}/L + 1 ppm Ba	99.1%	Low filtrate. Aeration or adding $BaCl_2$ wet makes a difference.

Table 4 (cont'd)

Pptn. Test	Reagent Addn/L	Additional Mechanical Stirring Time	Settling Time and Filtration	Filtrate Ra^{226} Assay	% Ra-Removal	Remarks
9.	671 mg $BaCl_2 \cdot 2H_2O$/L added as 35.7 g $BaCl_2 \cdot 2H_2O$/100 ml	30 min. aeration	72 h settling + decant filtered thru 0.45 μm filter	18 pCi Ra^{226}/L + 1 ppm Ba	99.6%	Precipitation formed in 1000 ml cylinder. Lower filtrate in Ra^{226}.
10.	140 mg H_2SO_4 + 673 mg $BaCl_2 \cdot 2H_2O$ as 35.7 mg/ /100 ml	"	"	80 pCi Ra^{226}/L + 1 ppm Ba	98.3%	Pptn in 1000 m/cylinder for better settling. Addn of $BaCl_2$ to filtrate made solution milky.
11.	27 g $CaCO_3$/L added to pH 1.0%. No ppte. Added 140 mg H_2SO_4 + 673 mg $BaCl_2 \cdot 2H_2O$ as 35.7 mg /100 ml.	"	"	6 pCi Ra^{226}/L + 2 ppm Ba	99.9%	$CaCO_3$ addn to pH 1.0% produced 6 pCi Ra^{226}/L filtrate. No ppte at pH 1.0%. Filtrate below federal criteria.
12.	33 g $CaCO_3$/L added to pH 2.01. Fine ppte. Added 140 mg H_2SO_4 + 673 mg $BaCl_2 \cdot 2H_2O$	"	"	6 pCi Ra^{226}/L + 2 ppm Ba	99.9%	Produced filtrate to 6 pCi Ra^{226}/L to suit federal criteria. Fine ppte would have to be disposed of.
13.	37 g $CaCO_3$/L added to pH 4.3. Large amt. Fe-ppte Added 140 mg H_2SO_4 + 673 mg $BaCl_2 \cdot 2H_2O$	"	"	< 5 pCi Ra^{226}/L + 2 ppm Ba	99.9%	Filtrate is < 5 pCi Ra^{226}/L to suit federal criteria. Large volume of ppte to be disposed of.
14.	Only 2440 mg $BaCl \cdot 2H_2O$ added, to monitor Ra, Ba and SO_4 removal	"	"	7 pCi Ra^{226}/L + 20 ppm Ba + 9 ppm SO_4	99.9%	Filtrate is 7 pCi Ra^{226}/L. to suit federal criteria. Ra low, Ba increased by 20 X & SO_4 low. See Fig. 1.
15.	1220 mg $BaCl \cdot 2H_2O$ added, to monitor Ra, Ba and SO_4 removal	"	"	52 pCi Ra^{226}/L + 2 ppm Ba + 48 ppm SO_4	98.9%	Filtrate increased to 52 pCi Ra^{226}/L, and 480 ppm SO_4 with 1/2 of $BaCl_2$ used in test 14.

Table 4 (cont'd)

Pptn. Test	Reagent Addn/L	Additional Mechanical Stirring Time	Settling Time and Filtration	Filtrate Ra^{226} Assay	% Ra-Removal	Remarks
16.	1830 mg $BaCl_2 \cdot 2H_2O$ added, to monitor Ra, Ba and SO_4 removal	30 min. aeration	72 h settling + decant filtered thru 0.45 µm filter	16 pCi Ra^{226}/L + 2 ppm Ba + 240 ppm SO_4	99.7%	Filtrate decreased to 16 pCi Ra^{226}/L, and 240 ppm SO_4 with 50% more $BaCl_2$ added as in test 15.
17.	Repeat of test 9 with less $BaCl_2$ i.e., 535.3 mg $BaCl_2 \cdot 2H_2O$	"	72 h settling + decant filtered thru 0.45 µm millipore filter	51 pCi Ra^{226}/L + 1 ppm Ba	98.9%	Better Ra filtrate with less $BaCl_2$ than test 9.
18.	Repeat of test 9 with less $BaCl_2$ i.e., 398 mg $BaCl_2 \cdot 2H_2O$	"	"	35 pCi Ra^{226}/L + 0.8 ppm Ba	99.3%	Improved filtrate with less $BaCl_2$ than Test 9.
19.	Repeat of test 9 with less $BaCl_2$ i.e., 260 mg	"	"	66 pCi Ra^{226}/L + 3 ppm Ba	98.6%	Ra removal falling off with decreased addn of $BaCl_2$.
20.	122.8 mg of $BaCl_2 \cdot 2H_2O$ added as 35.7 mg/L liquor. Repeat of Test 9 with less $BaCl_2$ in 1000 ml cylinder	"	"	21 pCi Ra^{226}/L + 1 ppm Ba	99.6%	Added 5% of stoichiometric amt of $BaCl_2$ to attain respectable 21 pCi Ra^{226}/L filtrate.
21.	Repeat of test 8 with 122.8 mg $BaCl_2 \cdot 2H_2O$ + 140 mg H_2SO_4	"	"	470 pCi Ra^{226}/L + 0.8 ppm Ba	99.0%	Addn of H_2SO_4 no improvement over test 20. Additional H_2SO_4 cost required.
22.	Repeat of test 11 with $CaCO_3$ addition to pH 1.03. 140 mg H_2SO_4 and 122.8 mg $BaCl_2 \cdot 2H_2O$	"	"	22 pCi Ra^{226}/L + 3 ppm Ba	99.5%	Filtrate assumed Fe^{3+} coloration on $CaCO_3$ addn to pH 1.03. Not as low barren as test 11 at 6 pCi Ra^{226}/L.

Table 4 (cont'd)

Pptn. Test	Reagent Addn/L	Additional Mechanical Stirring Time	Settling Time and Filtration	Filtrate Ra^{226} Assay	% Ra-Removal	Remarks
23.	Repeat of test 12 with $CaCO_3$ addn to pH 2.01, 140 mg H_2SO_4 and 122.8 mg $BaCl_2 \cdot 2H_2O$	"	"	26 pCi Ra^{226}/L	99.5%	Colloidal ppte at pH 2.01 with $CaCO_3$. Not as Ra^{226} free as test 12 at 6 pCi Ra^{226}/L.
24.	61.4 mg $BaCl_2 \cdot 2H_2O$/L added	"	"	159 pCi Ra^{226}/L + 1 ppm Ba	96.7%	Pptn visible.
25.	30.7 mg $BaCl_2 \cdot 2H_2O$/L added	"	"	275 pCi Ra^{226}/L + 1 ppm Ba	94.3%	Slight ppte.
26.	15.4 mg $BaCl_2 \cdot 2H_2O$/L added	"	"	672 pCi Ra^{226}/L + ppm Ba	86.9%	No ppte visible.

DISCUSSION

Figure 2 shows a plot of the data from Table 4, after the $BaCl_2 \cdot 2H_2O$ was added as a solution, versus Ra^{226} level obtained in filtrate. This plot does not include results of pH adjustment tests with $CaCO_3$. A line was drawn through tests 24 to 26 results and extended to results of test 14. About 58% of the points, arranged in a typical "wild" variation of Ra^{226}-analyses, fell close to the line.

There was adequate SO_4 in the HCl recycle liquor (Table 3) to precipitate $RaBa(SO_4)_2$ without the addition of H_2SO_4, to provide SO_4. The tests with $CaCO_3$ addition, to adjust pH, produced iron cakes with up to 200 pCi Ra^{226}/g. These would cause another problem as they would have to be disposed of. The presence of excess free HCl in chloride liquors affects the dissolution rate of solid $BaCl_2 \cdot 2H_2O$. Sand-bed filtration appeared to be an improvement over millipore filters in preliminary testing. This would have an advantage in practice. Filtrates, after addition of $BaCl_2 \cdot 2H_2O$ to tailings pond, could be run through sand-bed filters before discharge to the water environment.

Table 5 presents an estimated reagent cost of Ra^{226} - removal from a composite 2nd stage HCl pilot leach of Denison ore plus washes. Attaining effluents of 6 and 7 pCi Ra^{226}/L, below federal guidelines of 10 pCi Ra^{226}/L, is going to be about 10 times more costly than settling for a recyclable level of 66 pCi Ra^{226}/L.

CONCLUSION

Test work has indicated that low concentrations of Ra^{226} may be obtained from HCl liquors, bearing several thousand pCi of Ra^{226}, by precipitation with $BaCl_2 \cdot 2H_2O$. However, the attainment of Ra^{226} filtrates, below 10 pCi Ra^{226}/L will cost (see Table 5) about 10 times that of a recyclable concentration of ≈66 pCi Ra^{226}/L - where toxic Ba will build-up.

These comments apply only to this particular HCl liquor. The work should be repeated on a typical 2nd stage HCl leach of Denison ore and washes.

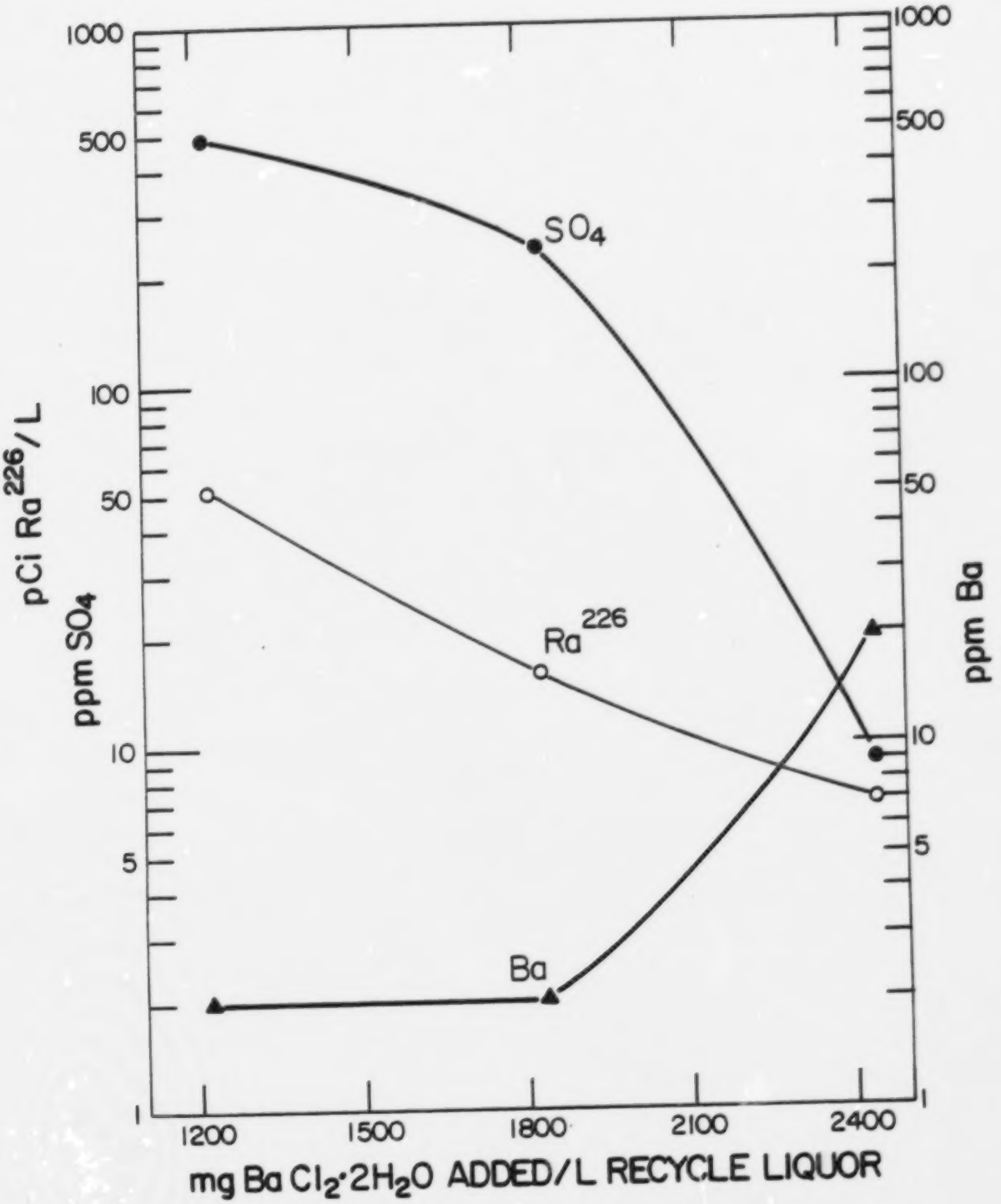

FIGURE 1. THE MONITORING OF RADIUM^{226}, SULPHATE AND BARIUM WITH INCREASED AMOUNTS OF $BaCl_2 \cdot 2H_2O$.

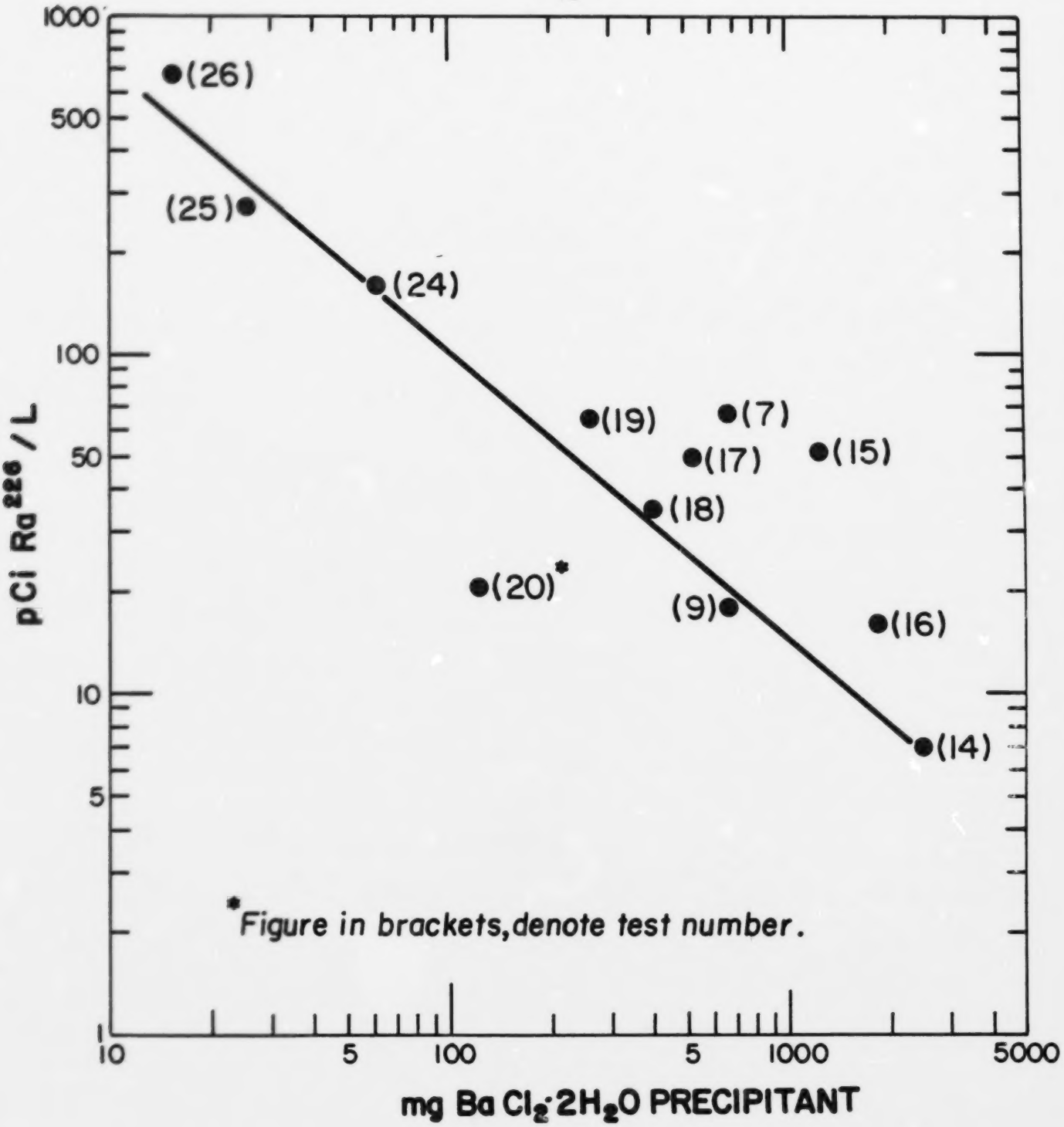

FIGURE 2. A PLOT OF WEIGHT OF $BaCl_2 \cdot 2H_2O$ ADDED VERSUS CONCENTRATION OF Ra^{226} OBTAINED IN PRECIPITATION FILTRATE.

Table 5 - The estimated reagent cost of precipitating Ra^{226} to low concentrations from a composite 2nd stage HCl pilot leach of Denison ore + washes

Test No.	Filtrate pCi Ra^{226}/L	Precipitation Reagents Added	Consumption Mg/L	lb reagent/lb U*	or kg reagent/kg U*	Estimated Reagent Cost /lb U*	or /kg U*
11	6	$CaCO_3$	27 000	31.95	70.45	$0.32	$0.71
		H_2SO_4	140	0.16	0.35	0.002	0.004
		$BaCl_2 \cdot 2H_2O$	673	0.796	1.76	0.18	0.40
					totals	$0.50	$1.11
9	7	$BaCl_2 \cdot 2H_2O$	2 440	2.888	6.37	0.65	$1.43
19	66	$BaCl_2 \cdot 2H_2O$	260	0.31	0.68	$0.07	$0.15

Reagent cost:

$BaCl_2 \cdot 2H_2O$ - 22.5¢/lb or 49.6¢/kg

$CaCO_3$ - 1.0¢/lb or 2.2¢/kg

H_2SO_4 - 1.2¢/lb 2.65¢/kg

Chemical Marketing Reporter 4 July 1983

* U = 0.845 g/L - The average of [2UCl + 3UCl] (U=1.10 g/L + U=0.59 g/L) first stage pilot-plant liquors to solvent extraction

ACKNOWLEDGEMENTS

The author is indebted to the following co-workers at CANMET: 1. A.E. Jones and J.B. Taylor, who individually performed different phases of this laboratory precipitation work, 2. L. Dalton, and his analytical group, for the Ra^{226} alpha spectrometry analysis, 3. R.J. Guest, and his analytical group, for analyses other than Ra^{226}.

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